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Short communication

Nutritional evaluation and comparison of extraction processes of parota [*Enterolobium cyclocarpum* (Jacq.) Griseb. Mimosaceae] almonds

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Abstract

This study aimed to evaluate the effect of different forms of mechanical extraction and treatment on the composition and nutritional value of parota almonds. The composition of raw, cooked, roasted and sprouted almonds was analyzed. The yield of recovered seeds was evaluated by comparing it with a hammer mill or manually. Three treatments were reevaluated with the dryer designed with processing times of 15, 30 and 60 minutes at 40°C. The germinated parota had a higher protein content (39.17%) followed by crude parota almond (34.9%). Thus it was feasible to take advantage of mechanical processing of parota almond for use as a potential protein resource for animal feeding.

Keywords: Extraction processes, Forest trees, Nutritional composition, Parota almond, Tropical legumes

Parota tree [*Enterolobium cyclocarpum* (Jacq) Griseb] produces fruits and leaves with nutritional potential for humans and cattle (Barrientos *et al.*, 2015). Fruit is a broad sheath, flattened, curved and indehiscent. When seeds are ripe, they have a hard and impermeable forehead so that insects seldom attack them. These characteristics are due to layers of lignified sclerosis that surround it (Rodríguez *et al.*, 2007). In Mexico, since pre-Hispanic times, these fruits have been consumed in sauces and soups. The seeds are consumed in several presentations as green, germinated, ripe, uncooked to cooked, or toasted and in many regions of the country, are consumed in various dishes (Olivares *et al.*, 2011 and Falkowski *et al.*, 2016); in addition, the leaves and fruits have been used as fodder and protein source for ruminants (Barros *et al.*, 2014; Álvarez *et al.*, 2003) to meet animal feed deficiency (Mukherjee *et al.*, 2018), while fruits have been used in non-ruminant diets, particularly in poultry trials (Iyayi *et al.*, 2006). Studies related to the anti-nutritional factors of parota trees are scarce in comparison to conventional foods (Teferedegne, 2007; Biabiany *et al.*, 2013). However, nutritional value and factors like protein and fiber, mainly in almonds of the parota tree, are changed depending on phenological state, processes and treatments during preparation for consumption (Ezenwa and Sotolu, 2000). Due to the physical and morphological characteristics of parota tree fruit, it is difficult to obtain seeds, which constitutes a limitation for its possible use in animal feeding on a bigger scale. Generally, seeds are recovered manually (Villalobos *et al.*, 2014) and trunks have been used with cuttings to crush the fruits (Zamora *et al.*, 2001). Currently, there are no specific processes for almond extraction, so the objective of this study was to compare different extraction processes of parota tree almond in order to get a comparison of the nutritional composition. The experiment was carried out at the Centro Interdisciplinario De Investigación para el Desarrollo Integral Regional Unidad Oaxaca (CIIDIR-Oaxaca).

Altitude was 1535 masl. The climate was temperate sub-humid (SEMARNAT, 2014). Parota almonds (Enterolobium cyclocarpum) were collected in three locations central subtropical zone in Mexico: Amacuzac (18°35′55″ N, 99°22′10″ W) with predominant Eutricfluvisol, loose granular soil, Zacatepec (18°39′23″ N, 99°11′28″ W) Pelicvertisol, expansive soils in the state of Morelos and Tonatico (18°48′18″ N, 99°40′09″ W) Pelicvertisol in the state of Mexico. Almonds were dried in a cocoa dryer, which consists of a 120-volt electric stainless-steel rotary drum with a frequency oscillator, minute fins distributed diagonally along the inner face of the drum, arranged in a triangular shape with a capacity of 100 kg, designed by CIIDIR Oaxaca (patent in process).

In order to evaluate the equipment, an experiment was carried out with a completely randomized design with five replicates, using 1 kg of almond per treatment, where the control treatment consisted of drying parota fruits at 45°C for 48 hours in a forced air oven, with manual recovery with scissors for 15, 30 and 60 minutes. A second mechanical treatment was carried out with a hammer mill using 13 mm mesh, where almonds were processed after drying in a forced air oven at 45°C for 48 hours. Three treatments were performed with the dryer designed in CIIDIR Oaxaca (features described above) where the following processing times were established: 15, 30 and 60 minutes with the dryer at 40°C. Response variables were the percent yield of whole and damaged seeds and unprocessed fruits.

The nutrient composition of samples from each collection site processed in the dryer (toasted) was compared with raw, cooked, boiled and germinated almonds. In order to remove the seed cover and analyze the raw almond, the seeds were heated to 92°C for 6 minutes and incubated in water at 28°C for five days. The seed cover was removed and almonds were triturated in a blender and dried at 60°C for 24 hours and ground to a particle size of 1-mm. The cooking process was made in an autoclave at 4 atmospheres of pressure at 121°C for one hour. The forehead was removed and ground to a grain size of 1-mm. Toasted almond was processed in the dryer at 38°C for one hour with movements every 20 minutes, removing seed cover with tweezers after toasting, first ground in a corn mill and later in a blade mill until the size of 1 mm was obtained.

For germination studies, almonds were initially heated to 75°C for 6 minutes and then incubated at 28°C for ten days. They were then moved to a wet chamber wrapped in absorbent paper when the radicle was visible until it reached 2 cm. Almonds were placed in pots in the greenhouse for 15 days, and irrigated every third day. Only green cotyledons were harvested. Cotyledons were crushed and dried using the previously mentioned processes to obtain 1 mm samples. Dry matter, nitrogen concentration, ethereal extract and ash were determined using the standard procedures (AOAC, 2000) for proximate chemical composition.

A complete random design with five replicates was performed to evaluate the equipment. The experimental variables were manual recovery, hammer mill, and dryer, along with their levels (3 different times). Results were analyzed according to a complete randomized design. Linear and quadratic contrasts of the processing time for the manual and mechanical processes with the designed equipment (SAS, 2006) were tested.

The results of seed yield with different processes were recorded (Table 1). The percentage of seeds obtained with mill tended to be lower ($p = 0.11$) than in the other processes 17.2 *vs* 25.7% (milled vs. others, respectively). There was no difference between the percentage of seed obtained between the machine and the manual process. Time response was linear ($p < 0.001$) and quadratic ($p < 0.002$) for the equipment and linear for manual ($p < 0.005$). Mechanization of processing needs to be evaluated in terms of energy costs, energy efficiency, waste generation and management, equipment cost, work efficiency and adaptability at any scale (Rangel *et al.*, 2004). Effects on nutritional quality should also be considered. In the mechanical processes of livestock feed, factors associated with feed (starch and protein), temperature and processing time might be critical in the nutritional value of processed feeds (Zinn and Ware, 2002). It was reported that during the roasting process, almonds reaching high temperatures could modify their color, taste and texture properties (Gou *et al.*, 2000), and that Maillard's non-enzymatic reaction might be present during dehydration (Hong and Berti, 2016). However, equipment was used at a maximum temperature of 45°C for one hour, temperature below 60°C where the formation of these complexes between the amino group of lysine and carbohydrates was carried out (Van Soest, 1982; Kocadağli and Gökmen, 2016).

According to the preparation process and origin, the composition of parota almond was recorded (Table 2). Interaction between localities and way of processing almonds in nutrients ($p < 0.05$) was detected. Germinated parota almonds had a higher protein content (39.17%), followed by crude parota almonds with 34.9% of protein content, and a lower protein content from cooked and toasted almonds (33.7 and 33.2%, respectively). On an average Zacatepec samples had higher protein content (38.29%). Crude fiber content was higher in germinated samples (6.37%) in relation to other processes, which were similar to each other (raw 2.69%, toasted 2.92% and cooked 1.66%), while Zacatepec samples had lower crude fiber content (2.5%). Fat content showed higher variability than other nutrients, which were different for all processes, with a higher content for the boiled parota (2.69%) followed by toasted (2.17%), raw (1.57%) and lesser with the germinated parota (0.93%). Zacatepec

Table 1. Effect of parota processing on seed yields

Process	Time (min)	Seeds obtained (%)	Seeds broken (%)	Fruit not processed (%)
Mill	0.066	17.2 (±1.37)	7.1 (±0.49)	23.1 (±1.73)
Mechanic	15	3.2 (±0.25)	0	87.2 (±7.41)
	30	32.8 (±2.13)	0	18.4 (±1.26)
	60	36.1 (±3.24)	0.04 (±0.003)	11.8 (±0.88)
Linear effect		P=0.0001	-	P=0.0001
Quadratic effect		P=0.002	-	P=0.0001
Manual	15	17.0 (±1.51)	0	54.8 (±4.05)
	30	29.8 (±2.32)	0	32.5 (±2.76)
	60	35.4 (±3.46)	0	14.4 (±1.18)
Linear effect		P=0.005	-	P=0.0001
Quadratic effect		P=0.41	-	P=0.73
CV (%)		29.2	96.2	25.1

samples showed lower ethereal extract content (2.5%). Germinated samples showed the highest ash/mineral concentration (5.33%) followed by crude (3.28%) and roasted (3.86%), while cooked parota almond showed the lowest fat content (2.58%). There were no differences between locations for ash.

Protein content in parota almond as reported by Barrientos *et al.* (2015), was between 19.54-30.34% in different regions of Jalisco, Mexico and it was higher than that reported in foliage (19.1%), which was used for sheep feeding in Quintana Roo, Mexico (Sosa *et al.*, 2004), or in dwarf goats feeding (19.4%) in Nigeria (Oni *et al.*, 2008). Jimenez-Hernandez *et al.* (2011) reported that the amount of starch in parota seed without testa was 75%. As expected, concentrations of nutrients in fruit were different from those of parota leaves (Carranza *et al.*, 2003). Nevertheless, leucaena leaf harvested in December had similar protein content (28.06%; Chauhan *et al.*, 2014). Indeed, parota was considered deficient in lysine and limited in methionine (Iyayi *et al.*, 2006) and it was necessary to identify anti-nutritional compounds (Barrientos *et al.*, 2015) such as protease inhibitors, saponins, flavonoids, tannins and phenols (Kaur *et al.*, 2018). However, Teferedegne (2007) did not detect tannins in the leaves, whereas Sosa *et al.* (2004) reported amounts that could be considered biologically important (0.027%) and associated with lower *in vitro* digestibility. Saponins were also detected (43.6 mg g^{-1} OM) as the equivalence of saponins found in *Quercus saponaria* (Rodríguez and Fondevila, 2012). In an experiment with sheep, where fruits were not processed, weight gain was lower (85g d^{-1}) in diets supplemented with 30% of parota fruit and seed with pod (Ezenwa and Sotolu, 2000). Parota fruit is

Table 2. Effect of processing and location of the parota in proximate composition (%)

Location	Process	Protein	Crude fiber	Crude fat	Ash
Amacuzac	Crude	30.65 (±1.90)^{e}	4.5 (±0.27)^{bc}	0.96 (±0.09)^{ef}	3.58 (±0.30)^{cde}
	Toasted	31.40 (±2.79)^{de}	4.8 (±0.43)b	2.04 (±0.17)^{bcd}	3.94 (±0.27)^{bcd}
	Boiled	31.46 (±2.26)^{de}	0.96 (±0.02)^{d}	2.68 (±0.32)^{ab}	2.18 (±0.33)^{e}
	Germinated	39.09 (±3.06)^{ab}	4.24 (±0.42)^{bcd}	0.48 (±0.05)^{f}	6.09 (±0.79)^{a}
Tonatico	Crude	34.16 (±4.44)^{dc}	1.45(±0.20)^{bcd}	1.85(±0.31)^{cd}	2.58 (±0.51)^{de}
	Toasted	35.33 (±4.94)^{c}	1.66 (±0.28)^{bcd}	2.24(±0.24)^{bc}	4.07 (±0.61)^{bcd}
	Boiled	31.88 (±7.97)^{de}	1.31 (±0.16)^{cd}	2.4 (±0.43)^{abc}	2.65 (±0.55)^{de}
	Germinated	35.9 (±8.25)^{dc}	10.15 (±1.82)^{a}	0.96 (±0.22)^{ef}	5.16 (±0.51)^{abc}
Zacatepec	Crude	39.98 (±5.99)^{a}	2.12 (±0.16)^{bcd}	1.91 (±0.26)^{cd}	3.71 (±0.51)^{cde}
	Toasted	34.44 (±6.54)^{dc}	2.31 (±0.41)^{bcd}	2.24 (±0.38)^{bc}	3.58 (±0.44)^{cde}
	Boiled	36.27 (±4.35)^{bc}	2.43 (±0.29)^{bcd}	2.98 (±0.53)^{a}	2.91 (±0.40)^{de}
	Germinated	42.47 (±5.52)^{a}	3.61 (±0.61)^{bcd}	1.36 (±0.14)^{de}	5.33 (±1.22)^{ab}
	Process effect	$p = 0.0001$	$p = 0.0001$	$p = 0.0001$	$p = 0.0001$
	Location effect	$p = 0.0001$	$p = 0.03$	$p = 0.0001$	$p = 0.22$
	Interaction	$p = 0.0001$	$p = 0.0001$	$p = 0.0003$	$p = 0.0163$
	CV (%)	3.76	39.91	14.88	16.55

[abcd] Means with different letters within column differed significantly ($p < 0.01$)

an important protein and energy resource. The presence of anti-nutritional factors in parota is not a limitation for incorporation into supplements in tropical production systems.

Studies of trees distribution with potential for cattle breeding in the central zone of Chiapas, Mexico, showed that *Enterolobium cyclocarpum* has higher adaptive amplitude spectra in altitude, temperature and soil types, and this was the reason to recommend a complete study on their concentration of nutrients as well as the presence of anti-nutritional factors (Gómez *et al.,* 2006). In the coastal plain of Chiapas, parota was also found to be one of the main isolated trees that remained despite deforestation in the state area (Carranza *et al.,* 2003). Recently, Australian researchers were interested in using parota as an exotic species because of its agronomic adaptability (Gómez *et al.,* 2006).

Due to its nutritional value, the mechanical exploitation of parota almonds could be considered a source of potential protein for animal and human diets in tropical conditions. However, it is necessary to continue with assessments of the quality of the protein and assays with livestock for efficient use. It was concluded that the best use of parota almond could be made in the feeding of ruminants because of the nature of these animals.

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